# Electrical Systems

*<Presenter>*

# Review

- Root Causes of Energy Inefficiency
- Roadmap to Maximize Energy Efficiency
  - Best Practices
  - Alternative Energy Sources
  - Controls
- Take Aways
- Seek Professional Help.

# ENERGY INEFFICIENCY OF DATA CENTERS

## ROOT CAUSES

- Physical Infrastructure is way OVERSIZED
- Power Requirements are greatly OVERSTATED
- Many Legacy INEFFICIENT Equipment are Incorporated
- Multi-stages of POWER CONVERSION

# ENERGY INEFFICIENCY OF DATA CENTERS

## ROOT CAUSES (continue)

## Electrical Infrastructure:

### System Configuration Criteria:

- Focus on Increased Reliability & Uptime to 99.999%
- Fault Tolerant

### Design / Sizing Concept:

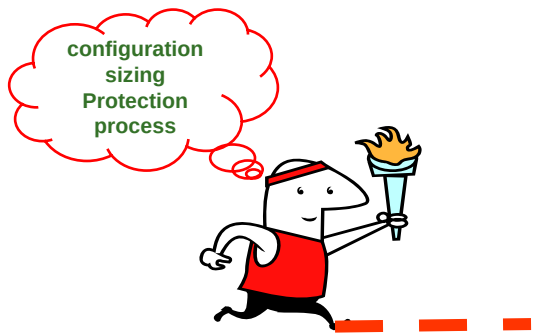
- Designed IT Load ➔ based on IT Nameplate plus future growth
- Data Center Floor Area ➔ based on Designed IT Load / (5-100 W/SF)
- UPS System Rating ➔ based on Designed IT Load + (20 – 50%)
- Standby Generator Sizing ➔ based on UPS system rating x 2 ++
- Lights ➔ based on (3 W / SF) x Data Center Floor Area
- Physical Rooms size(s) of UPS / Battery / Switchgear ➔ based UPS systems physical sized ++

### Power Protection:

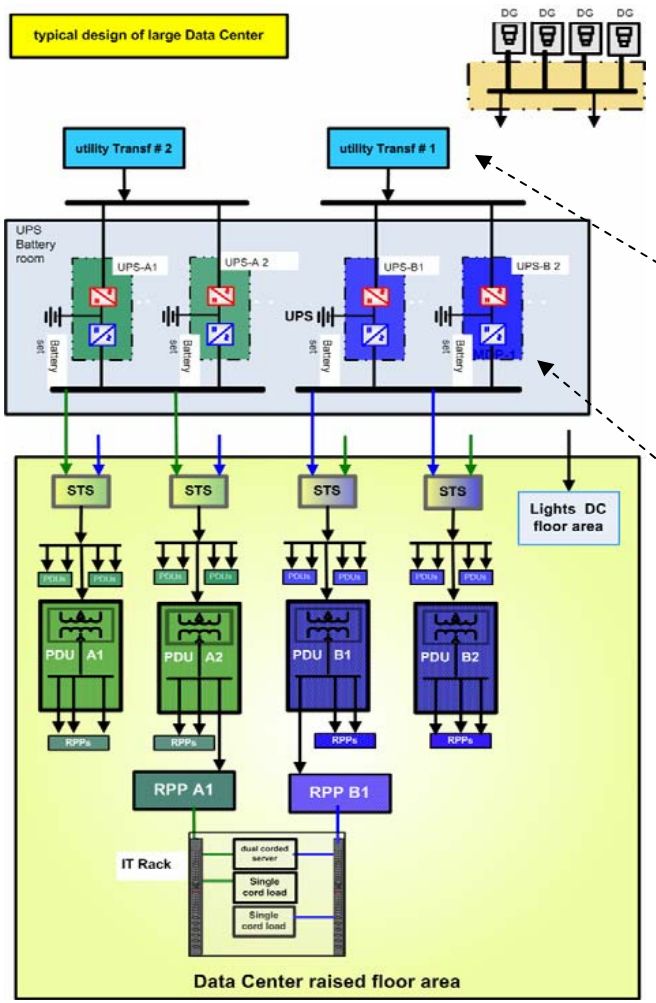
- Relying on UPS Power for voltage regulation and back-up

### Purchasing Process:

- Lowest Bid / Cheaper Price Wins



# ENERGY INEFFICIENCY OF DATA CENTERS




## ROOT CAUSES (continue)

### Electrical Infrastructure:

- ❑ **Standby Generators**
  - Oversizing
  - Redundancy Exceeds N+1

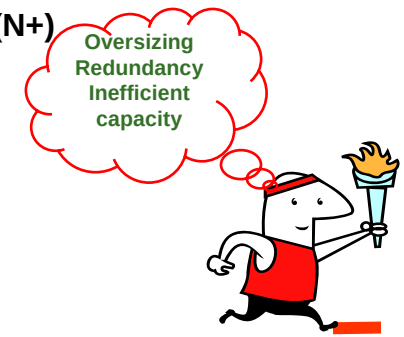
**Higher power consumption of Block heaters, and water & Oil pumps Up to 5%**

- ❑ **Transformers**
  - Oversizing
  - Inefficient

**Higher transformers losses up to 3%**

- ❑ **UPS**
  - Low Load Capacity Due To
    - Oversizing
    - Multi-Stage Redundancy 2 (N+)
  - Inefficient UPS Topology
  - Low Input Power Factor
  - High Input Current THD

**Higher UPS losses up to 25%**



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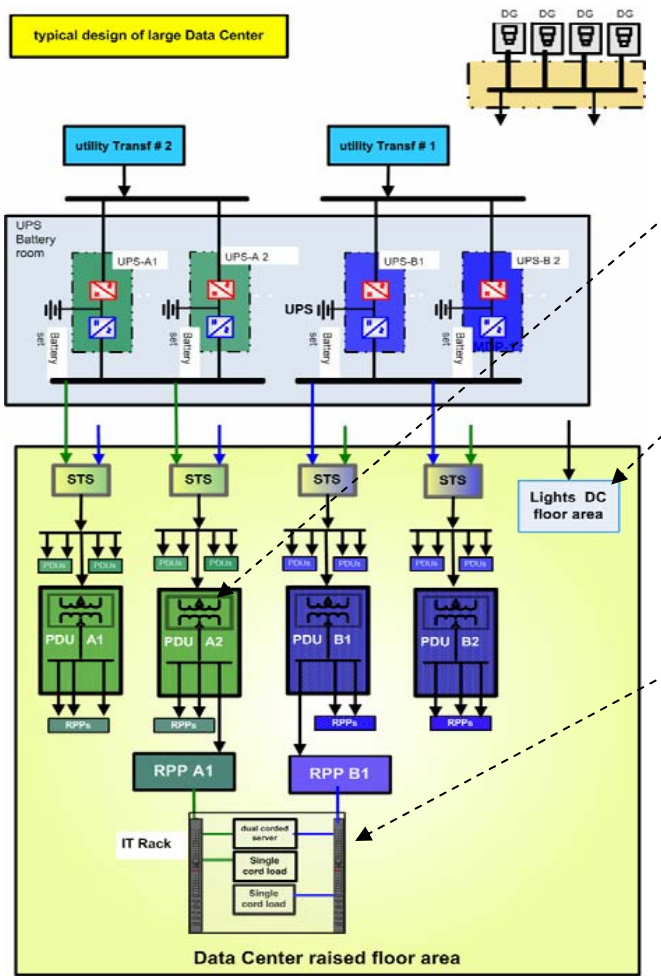



## ROOT CAUSES (continue)

## Electrical Infrastructure:

- **PDU**
  - Excessive Use of PDUs. 4 – 6 X IT designed Load
  - Inefficient Transformers

**Higher transformers losses up to 3%**

- **Lights**
  - Unused Floor Space
  - Use Of Inefficient Lights
  - No Lights Control Sensors

**Higher power consumption up to 5%**

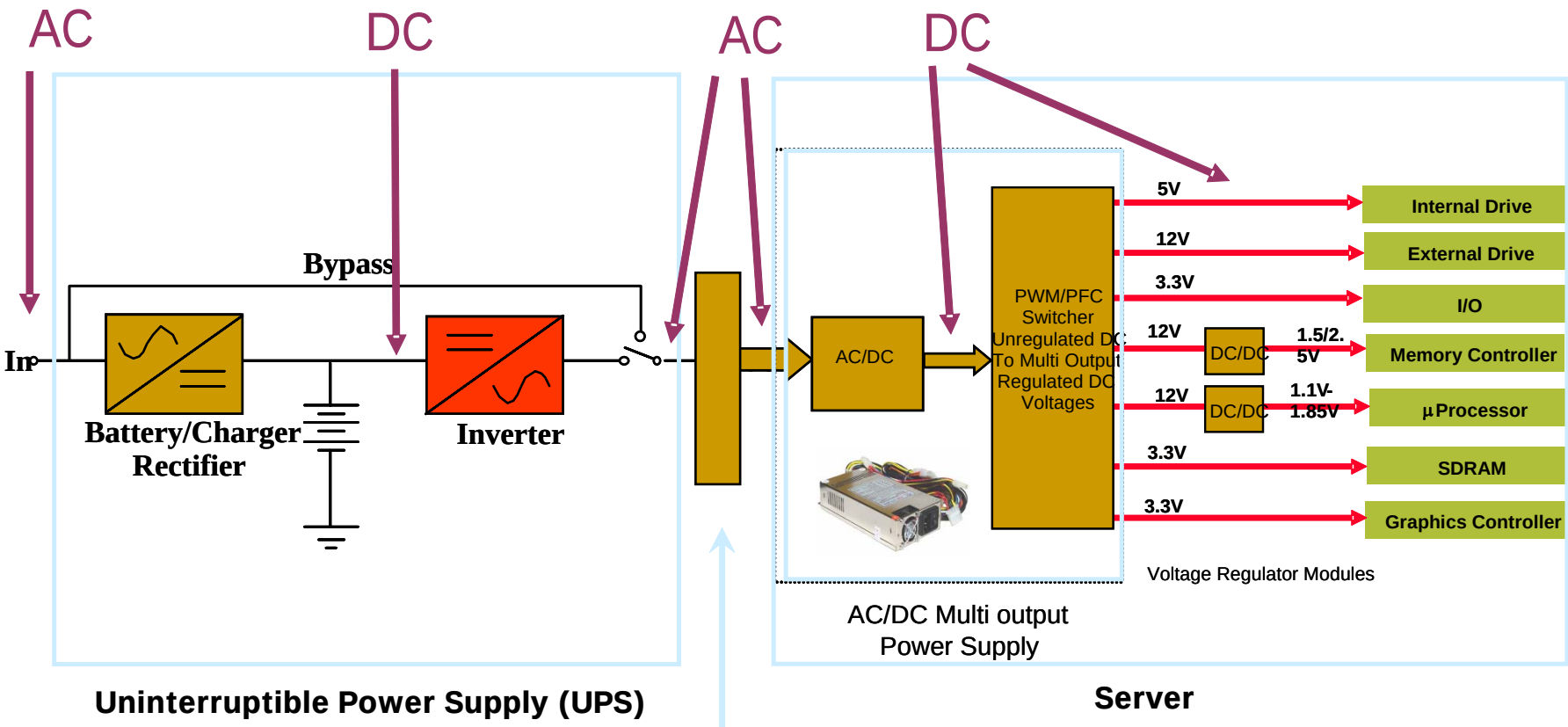
- **IT**
  - Sizing of IT load is based on Nameplate ++ growth
  - IT Low Power Factor
  - IT High Current Harmonic THD

**Higher cables & transformers losses**

# ENERGY INEFFICIENCY OF DATA CENTERS

## ROOT CAUSES (continue)

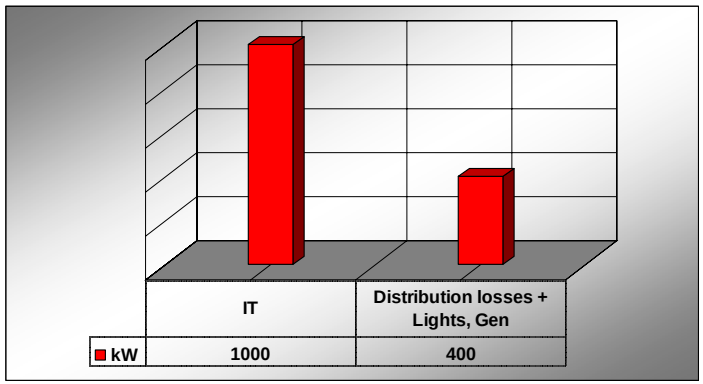
### Multi-stages of Power Conversions



# ENERGY INEFFICIENCY OF DATA CENTERS

## ROOT CAUSES (continue)

### Final Result



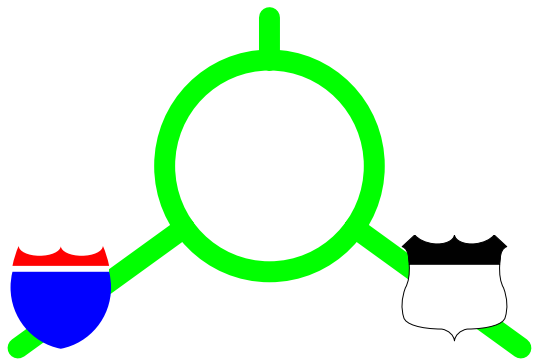

**Excessive Energy Waste up to 40%**

**LOW (Poor) DCiE FACTOR**

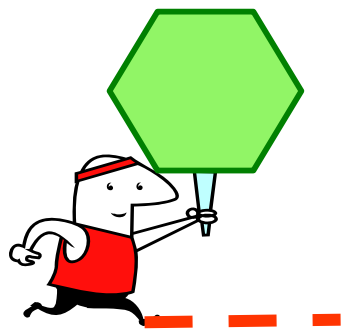
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## While Maintaining System Configuration Criteria

- Reliability & Uptime to 99.999%
- Fault Tolerant System



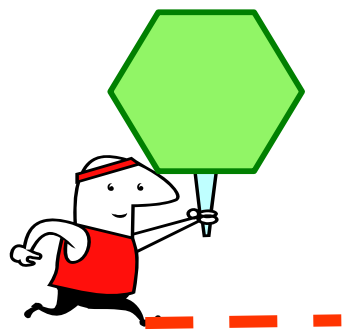
**OPTIMIZE POWER CONSUMPTION X OPTIMIZE TIME USAGE**



# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Driving Directions

- Best Practices
- Alternative Energy Source
- Controls (Thermostat, Sensors, ETC)



# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

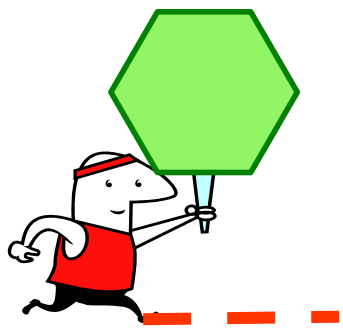
## Best Practices

### Managing UPS Load Capacity:

**UPS Sizing and Loading Can Significantly Affect UPS efficiency:**

- ✓ **Maximize UPS Load Capacity:**
  - **< 30% for N+ X configuration**
  - **< 40% for N configuration**
- ✓ **Specify / Consider UPS system that has higher Efficiency at 10 – 40% load capacity**

  **(Most UPS units in N or N+X configuration operate at 10% to 40% load capacity)**
- ✓ **Use / Evaluate Efficient UPS Topology:**
  - **Double Conversion with Filter**
  - **Delta Conversion**
  - **Rotary**
  - **Flywheel**
- ✓ **Consider Modular UPS (An Option to Maximize UPS Load Capacity)**



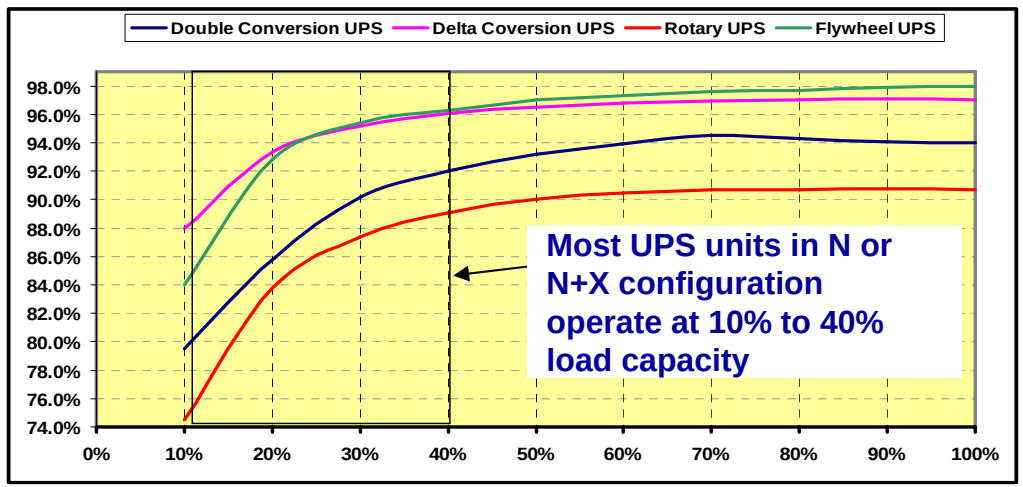
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

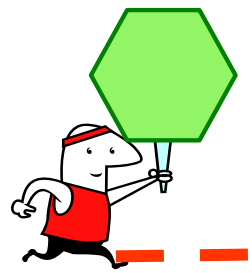
- **Managing UPS Load Capacity (continue:)**

  **Example:** 10% difference in UPS efficiency per 1000 kW IT Load results in approx. 900 MWhr of Energy saving per year and approx $400K of Energy saving over 5 years.

**Result >> Overall Energy Effectiveness is high.**




Optimize Power



# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

- **UPS Input Specs**
  - ✓ **Specify / Consider UPS system with Lower Input Current THD at 10- 40% load capacity**
  - ✓ **Specify / Consider UPS system with higher Power Factor at 10– 40% load capacity.**

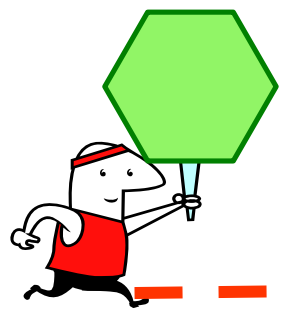
**NOTE:**
**Input Current THD increases, and PF decreases when UPS operates at lower load capacity**

| UPS without Filter | | | |
|---|---|---|---|
| Load % | P.F. | THD | Losses |
| 10 | 0.650 | 63.0 | 15.00% |
| 25 | 0.695 | 60.5 | 12.80% |
| 50 | 0.764 | 40.5 | 8.40% |
| 75 | 0.800 | 30.0 | 7.30% |

| UPS with Filter | | | |
|---|---|---|---|
| Load % | P.F. | THD | Losses |
| 10 | 0.770 | 25.0 | 15.00% |
| 25 | 0.820 | 10.0 | 8.00% |
| 50 | 0.840 | 6.0 | 6.00% |
| 75 | 0.900 | 5.0 | 5.60% |

**Example:** **10% difference in Input current THD per 1000 kW IT Load results in approx. 900 MWhr of Energy saving per year and approx $400K of Energy saving over 5 years.**

**Result >> Overall Energy Effectiveness is high**

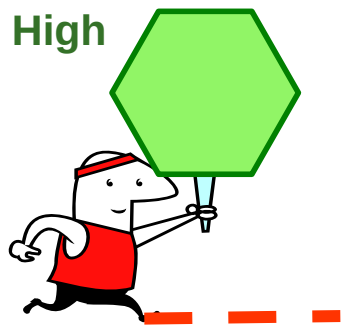


# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

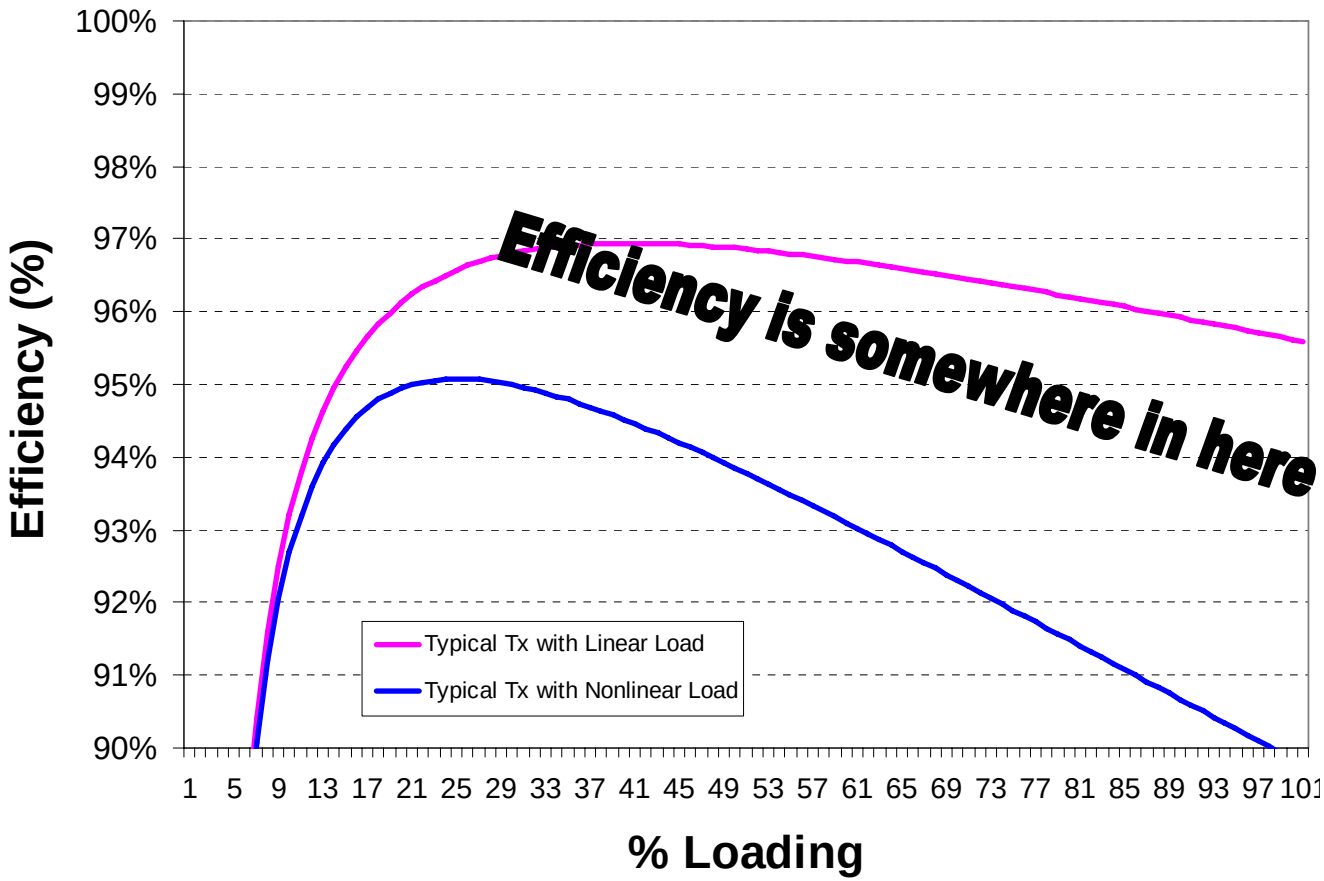
## Best Practices (continue)

- **Transformers & PDUs (with built-in Transformer):**
  - ✓ **Specify / Consider Transformers with Higher Efficiency:**
    - ➢ **Transformers with 80°C temperature rise. For example:**
      - **A transformer with an 80°C temperature rise uses 13- 21% less operating energy than a 150°C rise unit.**
      - **The higher-efficiency 80°C rise transformers have a first-cost premium, but a shorter payback than the less-efficient 150°C rise transformers.**
    - ➢ **NEMA TP1 Transformers.**
    - ➢ **Higher Efficient Transformers that exceed Benchmarking Efficiency:** ASHRAE 90.1, EPACT 2005, TP1
  - ✓ **Install Low voltage (LV) transformers outside the raised floor area**
  - ✓ **Reduce the number of PDUs (with built-in Transformer) inside the Data Center.**

**Result >> Overall Energy Effectiveness is Medium / High**



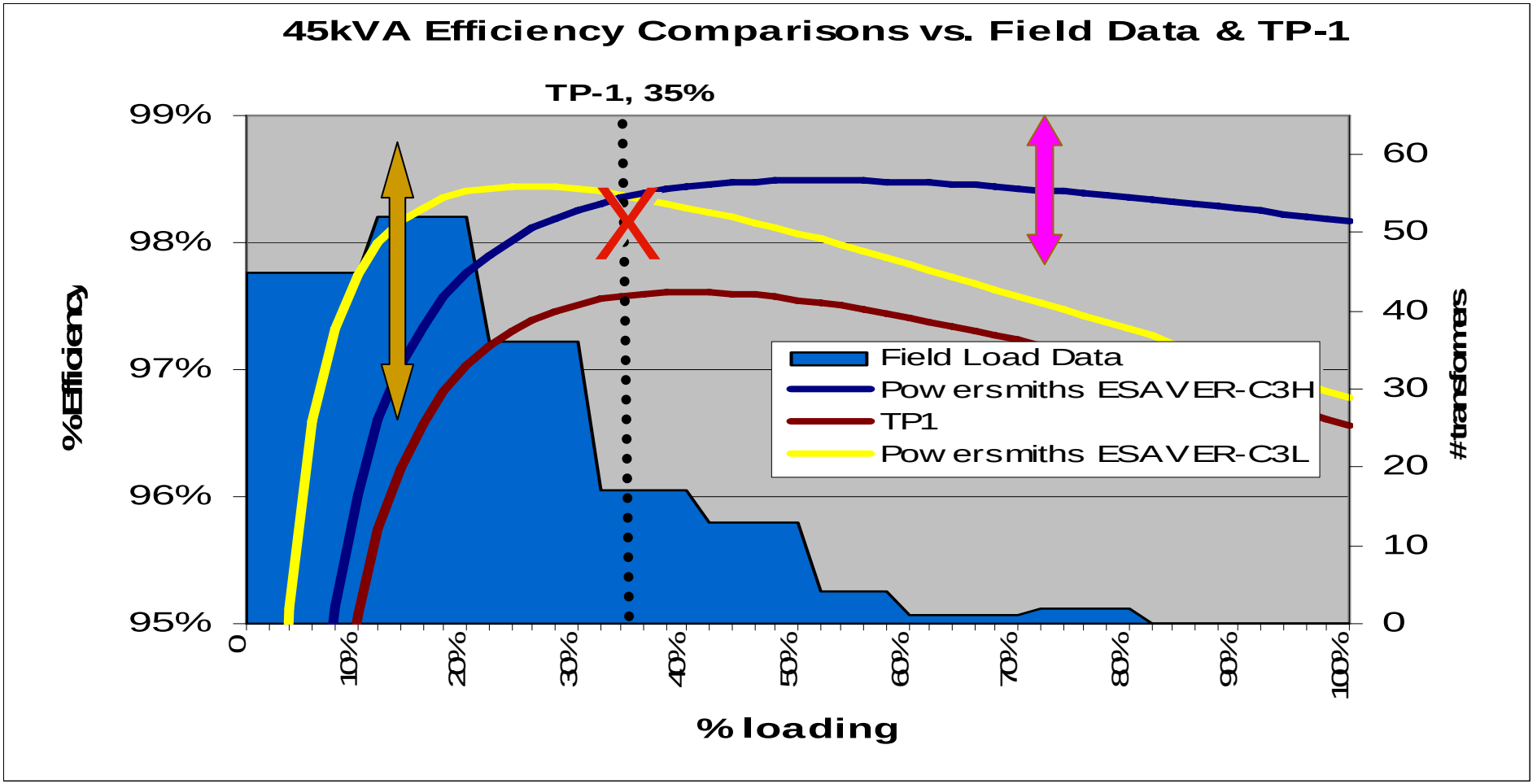
# Energy Deficiency Typical 112.5kVA Nonlinear UL listed transformer




*Significant variation in efficiency over load range & concentration of electronic equipment*

**Courtesy of PowerSmiths**

# High Performance vs. TP1 (EPACT 2005) transformer




ESAVER C3L -> Light Load optimized, C3H -> Heavy Load optimized

Courtesy of PowerSmiths

# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

### Stand-By Generators

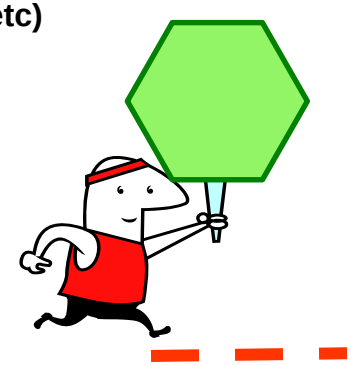
- ✓ Right Sizing of Stand-by Generator
- ✓ Maintain N+1 Redundancy
- ✓ Check with the emergency generator manufacturer on how to reduce the overall energy consumption of heater water jacket(s) (HWJ), i.e. temperature control

**Result >> Overall Energy Effectiveness is low**

### Lights

- ✓ Use energy Efficient Lights
- ✓ Lights in raised floor area are located above the aisles
- ✓ Maintain regular and proper maintenance includes periodic cleaning and re-lamping
- ✓ Replace older coil / core Ballasts type with new efficient electronic ones.
- ✓ Remove the Ballast from the fixture when the lamp is removed. (some Ballast types consume power even if the lamp is removed)
- ✓ Switch off lights in unused / occupied areas or rooms (UPS, Battery, S/Gear, etc)

**Result >> Overall Energy Effectiveness is low**



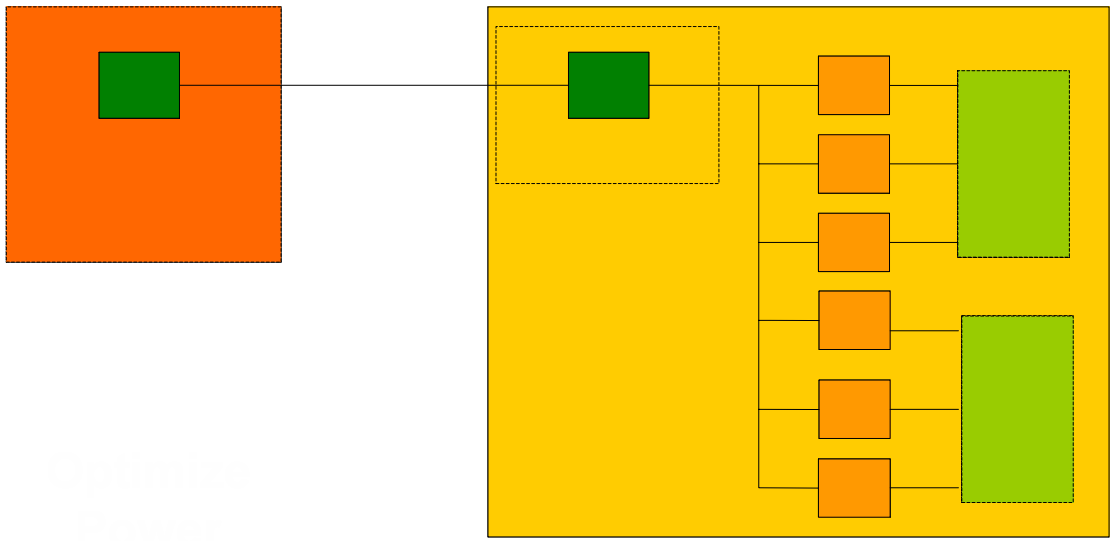
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

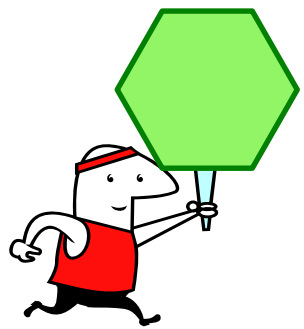
## Best Practices (continue)

- **DC Power Distribution**
  - ✓ **Eliminate two stages of power conversion.**

**Result >> Overall Energy Effectiveness is High**

### Facility-Level DC Distribution



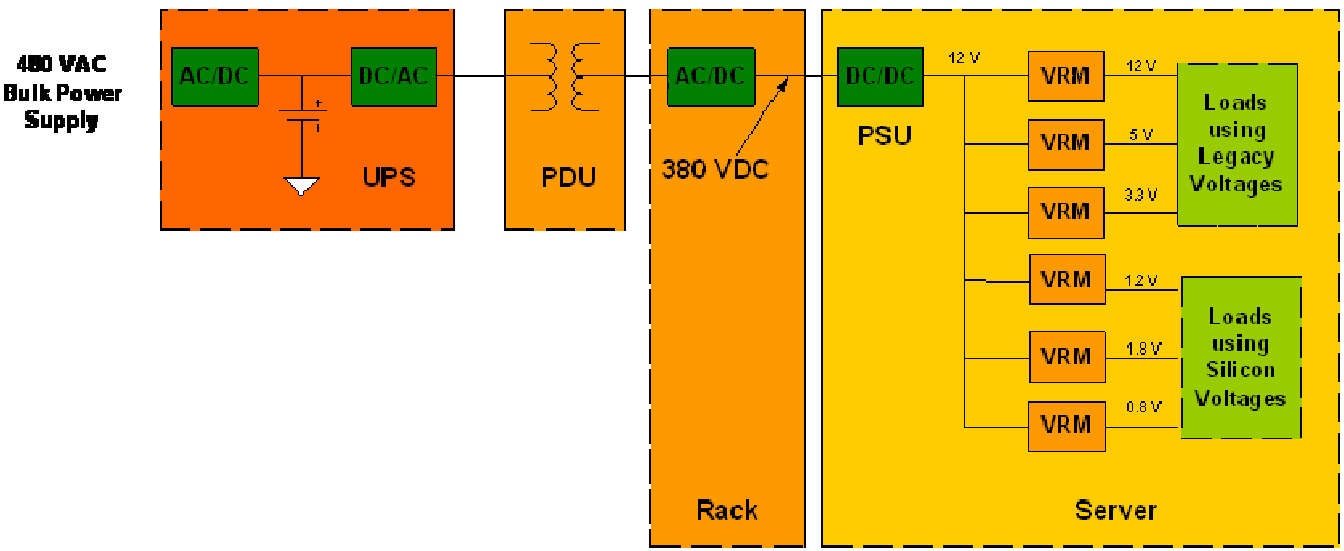


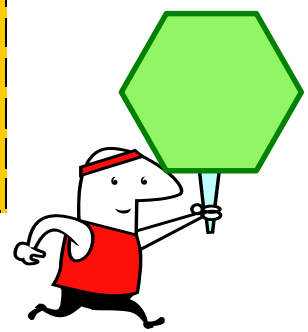
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

- **DC Power Distribution** (continue)

### Rack-Level DC Distribution



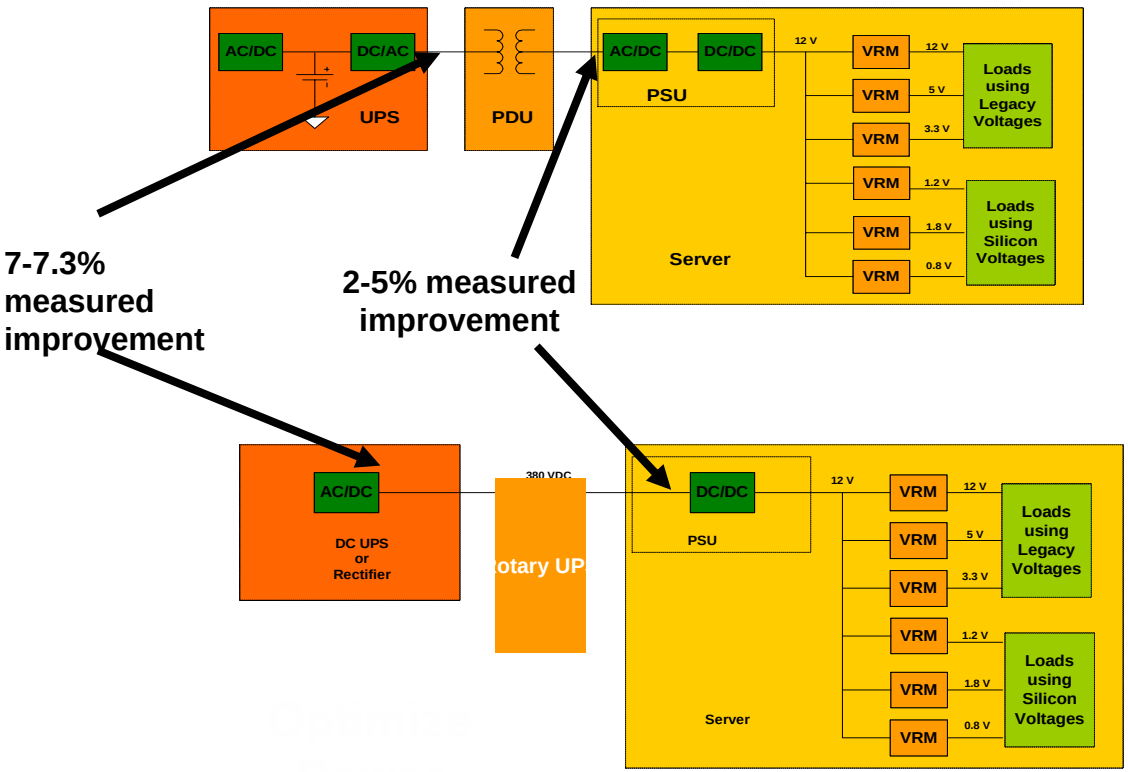



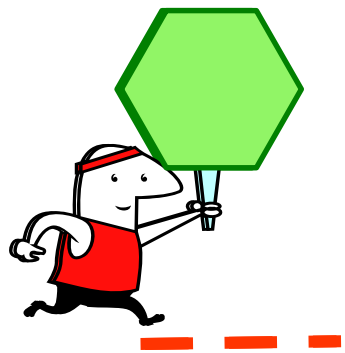
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

### DC Power Distribution (continue)

#### AC System Loss Compared to DC



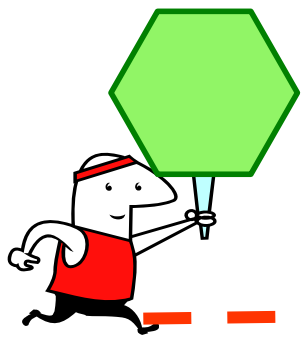
# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

- **Purchasing Process**
  - ✓ **Selection and Purchasing of Equipment should always be based not only on its initial purchase price or lowest bid but should also include its life operating energy cost,**
  - ✓ **Any time there is a new Data Center Faculty is built, an existing facility is expanded, or equipment is being replaced there is a significant opportunity to save on energy costs by selecting and installing cost-effective, energy-efficient equipment.**

**"The least expensive equipment to buy may cost much more to operate."**

**Result >> Overall Energy Effectiveness is High**

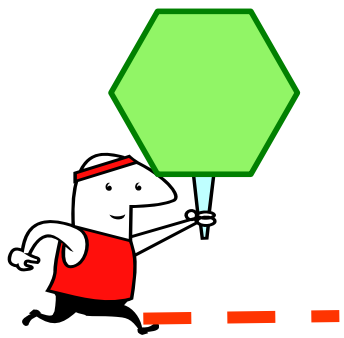


# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

## Best Practices (continue)

- **Awareness & Energy Management**
  - ✓ Raise awareness and develop understanding among Data Center staff about the financial and environment impact of energy savings.
  - ✓ Develop Effective energy management Program.
  - ✓ Perform Routine Energy saving opportunities and best practices for data centers
  - ✓ Review full system operation, and efficiency on regular basis.
  - ✓ Perform an Infra-Red (IR) test for the main transformers and other electrical systems
  - ✓ Improve the load balance between the phases
  - ✓ Change UPS DC capacitors if older than 5 years
  - ✓ **Metering:**
    - ✓ Install meters (EPMS) to measure instant DCiE values for the Data Center
    - ✓ Install monitoring equipment to measure system efficiency and performance.
    - ✓ install Meters in every RPP, PDU, STS, etc
    - ✓ Install Metered Power Strip in every IT Rack

**Result >> Overall Energy Effectiveness is Medium**



# ROADMAP TO MAXIMIZE ENERGY EFFICIENCY

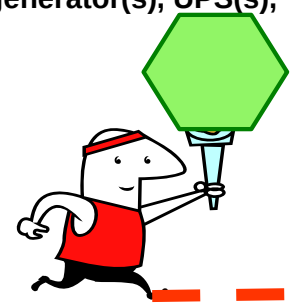
## Alternative Energy Source

- Employ alternate energy source to provide power for generator engine block heaters, lights (Data Center, UPS / Switchgear rooms, etc), etc.:
  - ✓ Solar
  - ✓ Wind
  - ✓ Fuel Cells
- Distributed Generation (DG):
  - ✓ Diesel or Gas- Fired Generators
  - ✓ Gas Turbines
  - ✓ Micro-Turbines
  - ✓ Fuel Cells
  - ✓ Wind
  - ✓ Bio-Mass

## Controls (Thermostat, Sensors, ETC)

- ✓ Contact the Stand-by Genenerator Manufacturer on how to reduce the overall energy consumption of the block heaters per year by using temperature (thermostat) control.
- ✓ Employ lighting controls such as occupancy sensors for data center, emergency generator(s), UPS(s), and Battery rooms

**Optimize Usage**



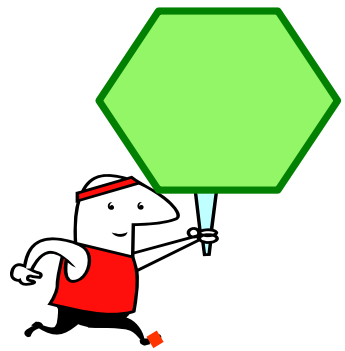
## Take Aways

- Distributing higher voltage (AC or DC) is more efficient
- Electrical power conversions are inefficient
- Highly efficient UPSs should be specified
- Highly efficient Transformers should be specified
- Highly efficient Lightings should be specified
- Highly efficient IT equipment power supplies should be specified
- Standby generation losses can be minimized
- On-site generation can improve reliability and efficiency
- Consider Alternative Energy Sources
- Raise awareness and develop Energy management Program
- Selection and Purchasing of Equipment should be based on operating energy cost.

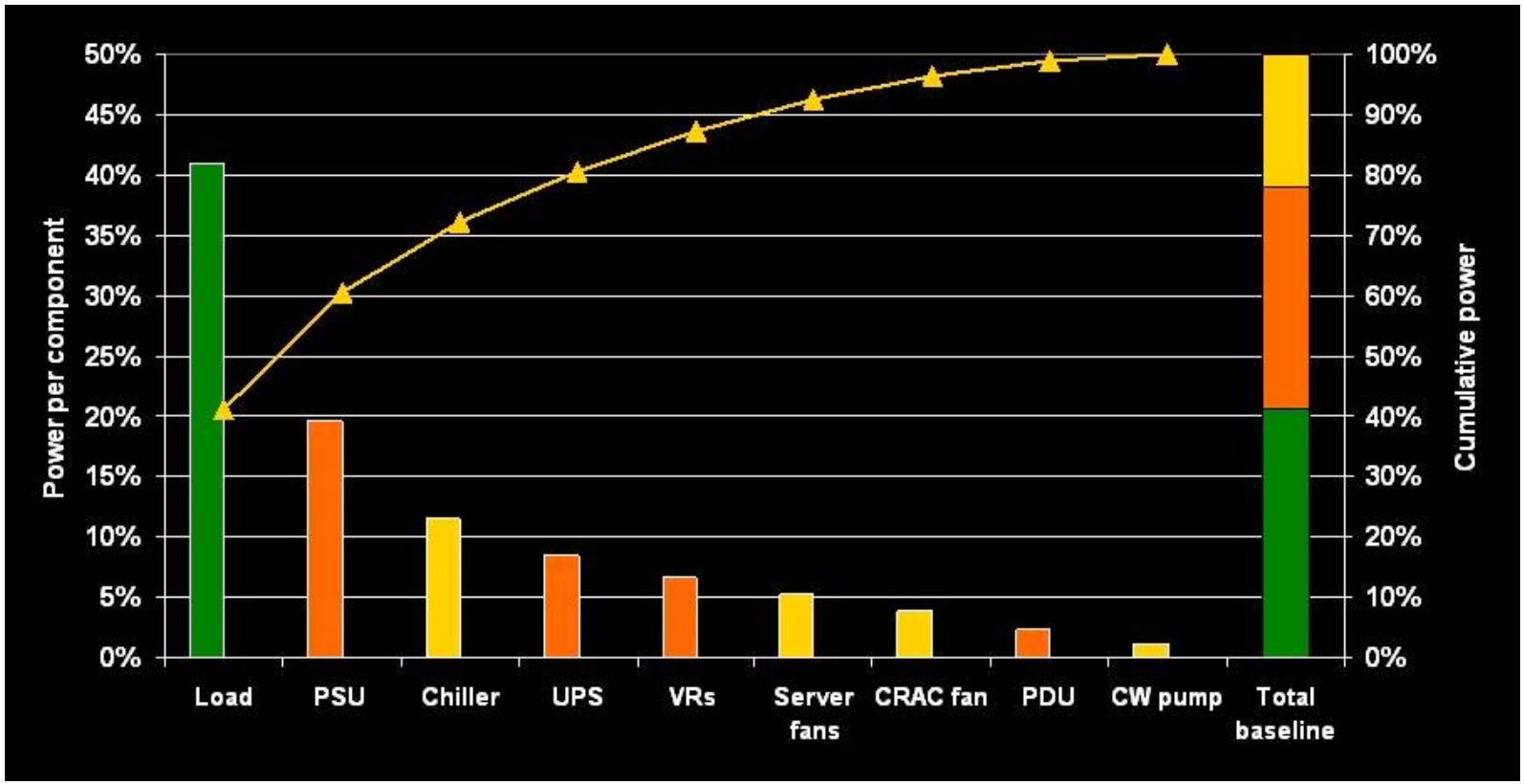
## Professional Help

This curriculum is not intended to provide answers to all related questions.

Professionals specialized in Energy Saving should be able to assist in identifying root causes of Energy Inefficiency / Waste, and maximizing Energy Efficiency.



# Overall power use in data centers

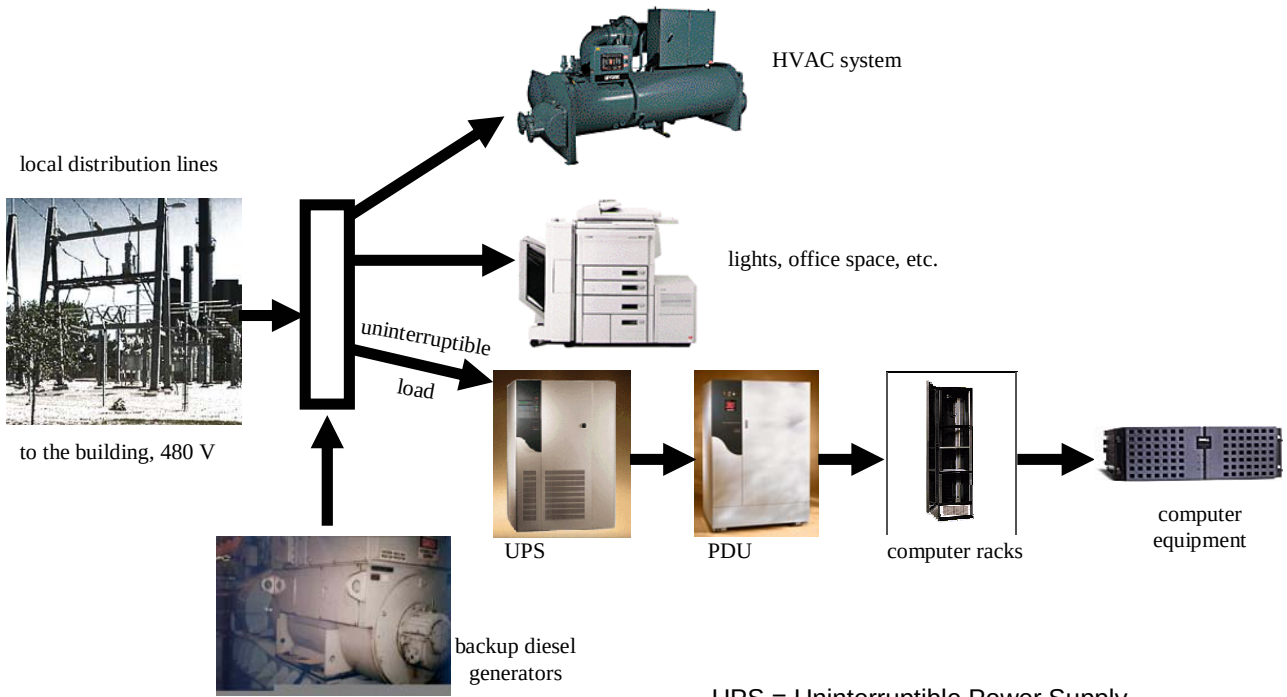



Courtesy of Michael Patterson, Intel Corporation

# Electrical Systems Efficiency

- Electrical distribution systems
- Lighting
- Standby generation
- On-site generation

# Electricity Flows in Data Centers



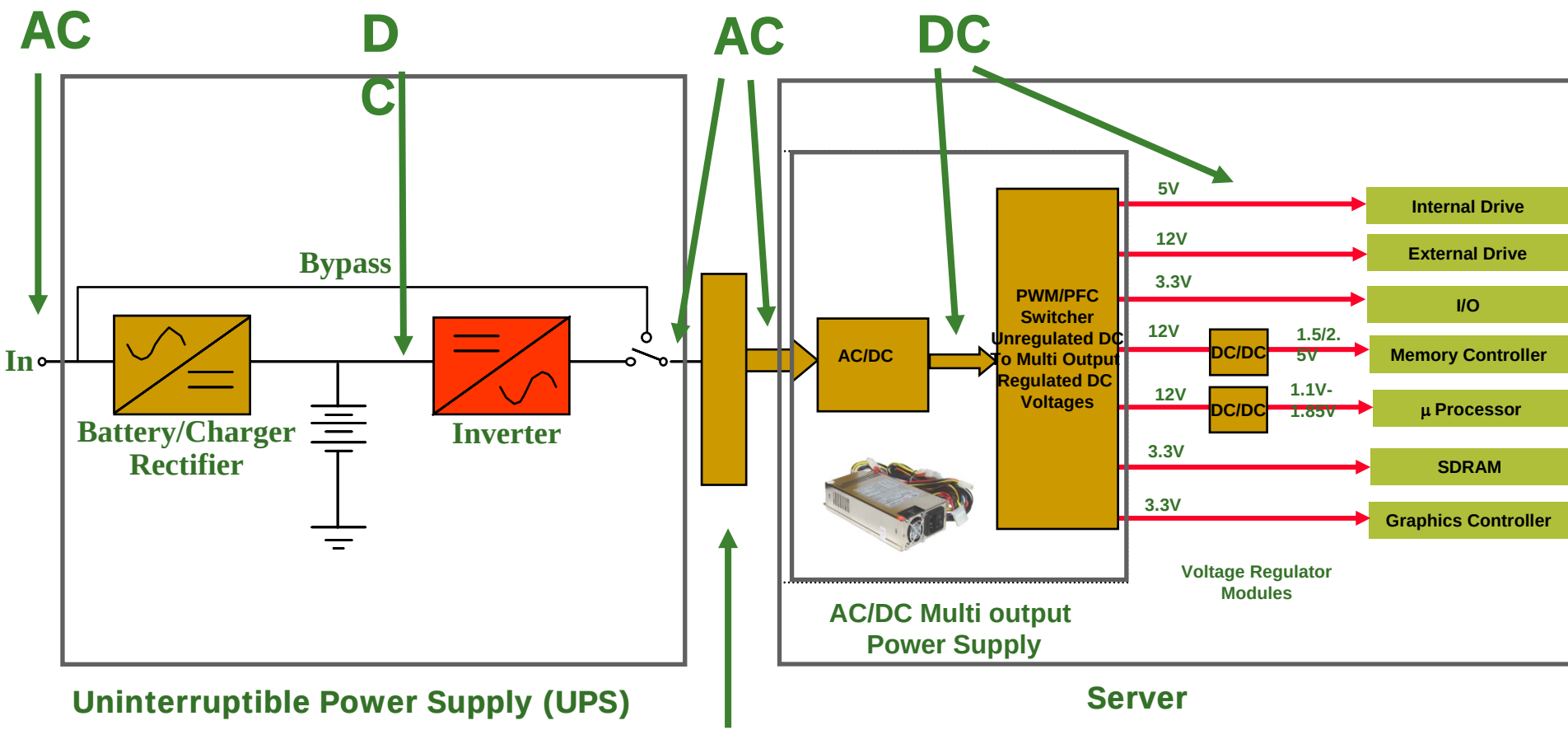

UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

# Electrical Distribution

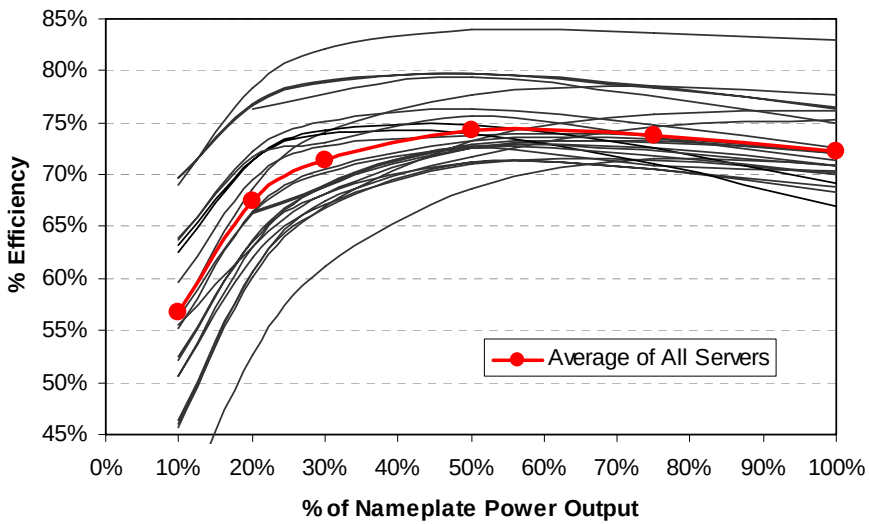
- Every power conversion (AC  DC, DC  AC, AC  AC) loses some power and creates heat
- Distributing higher voltage is more efficient and saves capital cost (wire size is smaller)
- Uninterruptible power supplies (UPS's) efficiency varies
- Power supplies in IT equipment efficiency varies

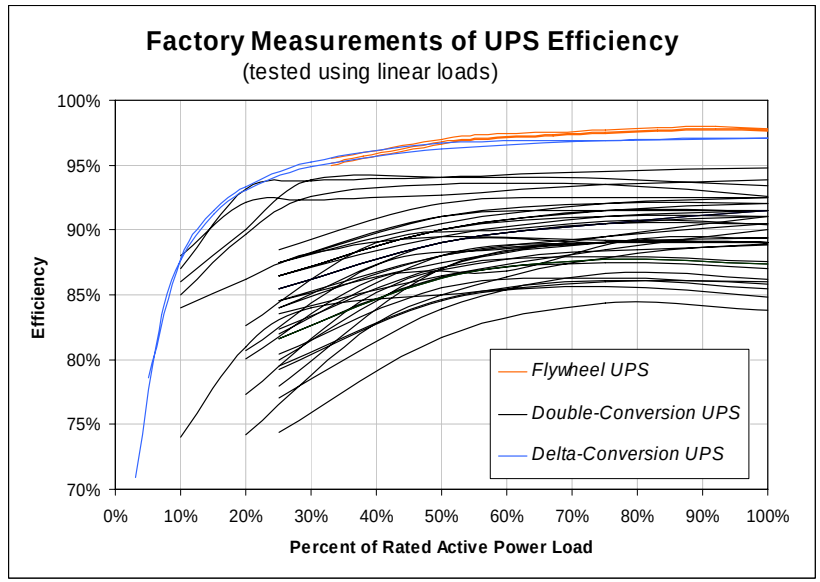
# Data center power conversions



# Electrical Power Conversions

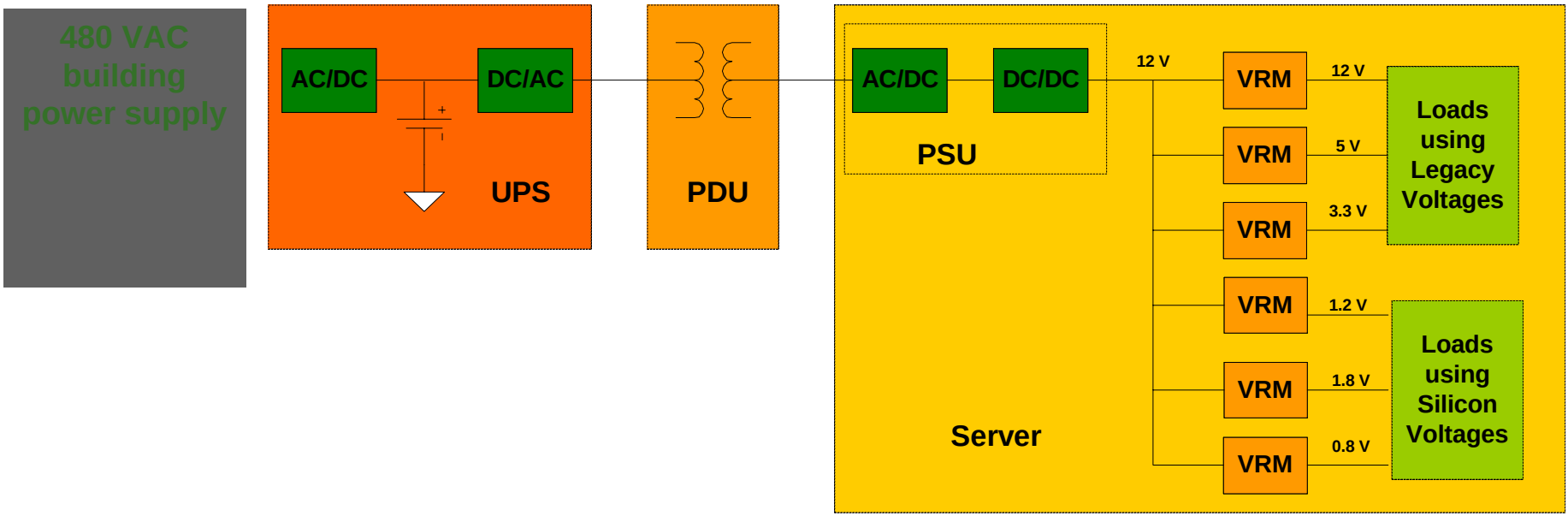
**Observed conversion losses suggested other solutions**



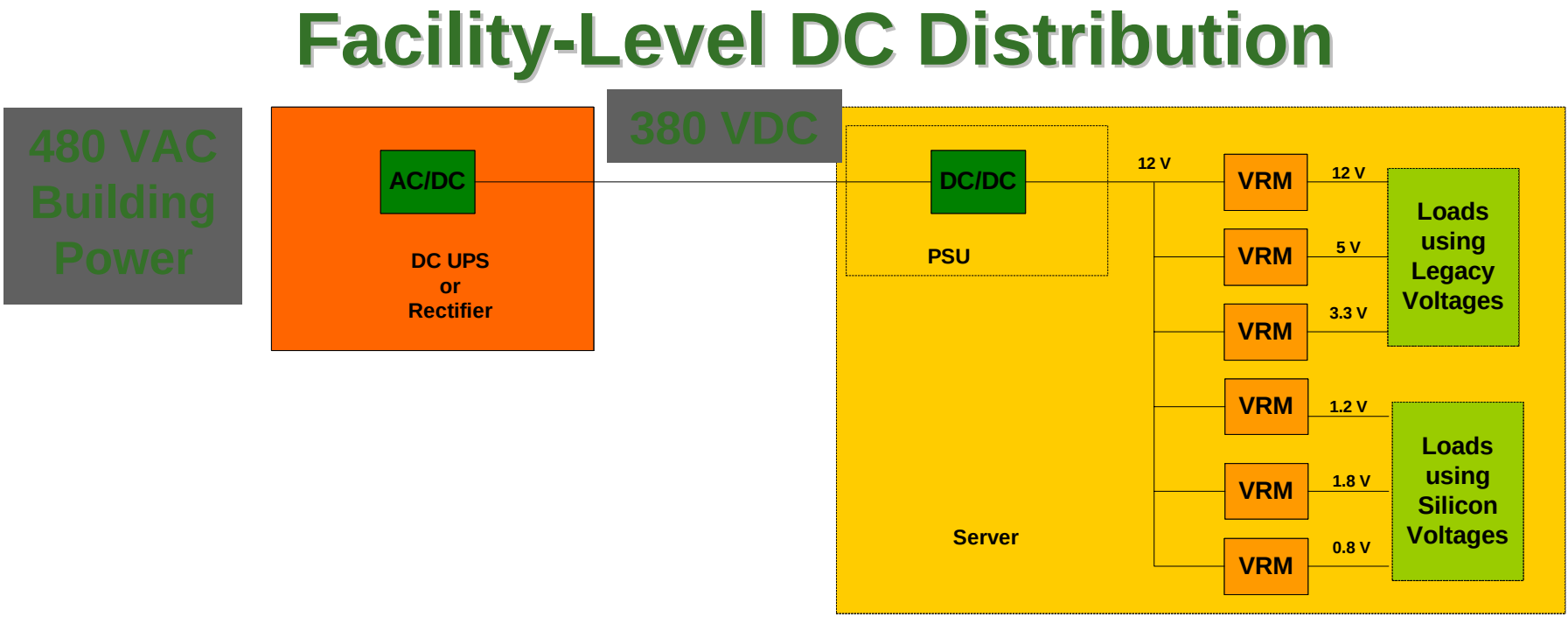



# LBNL DC Demonstration

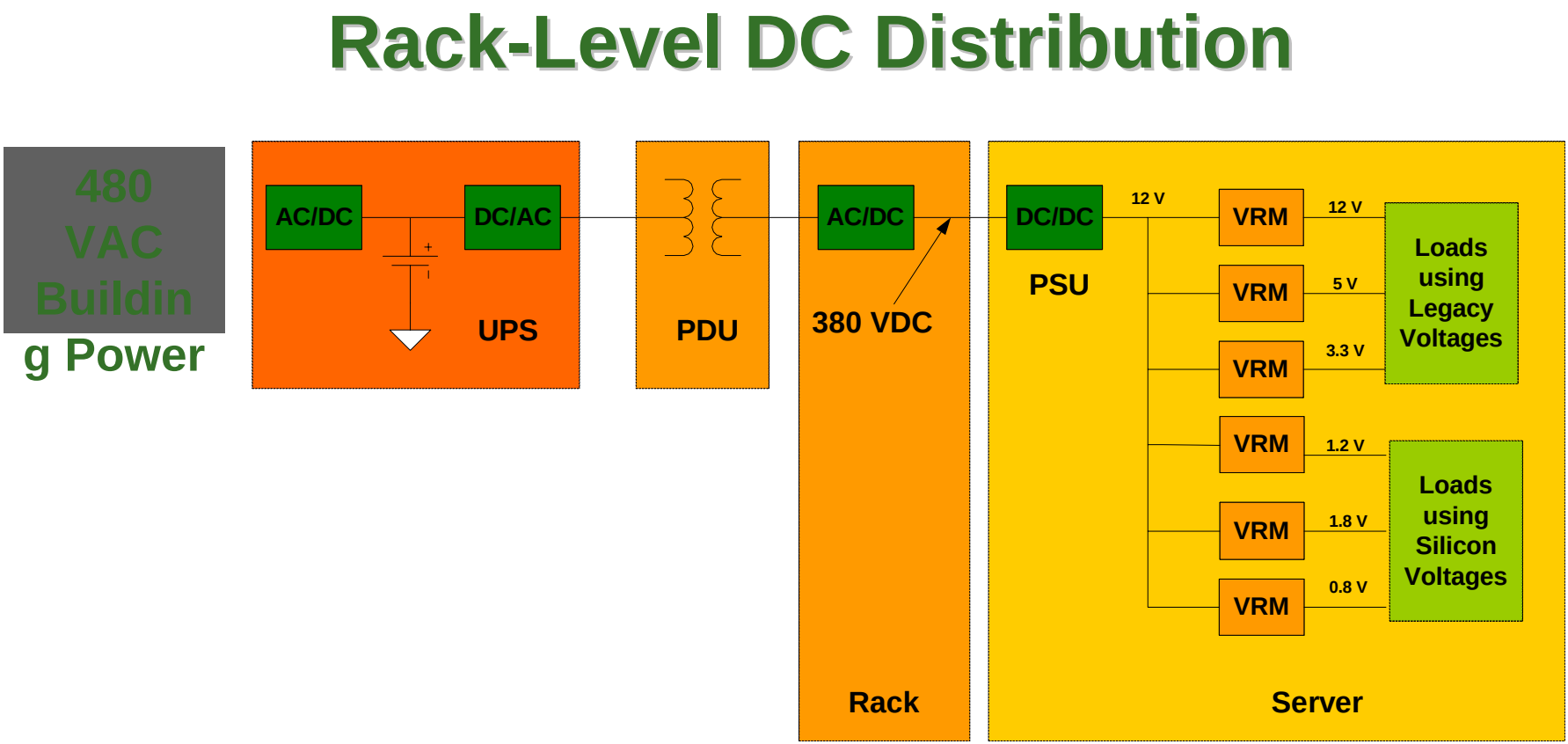
## Today: AC Distribution



# LBNL DC Demonstration



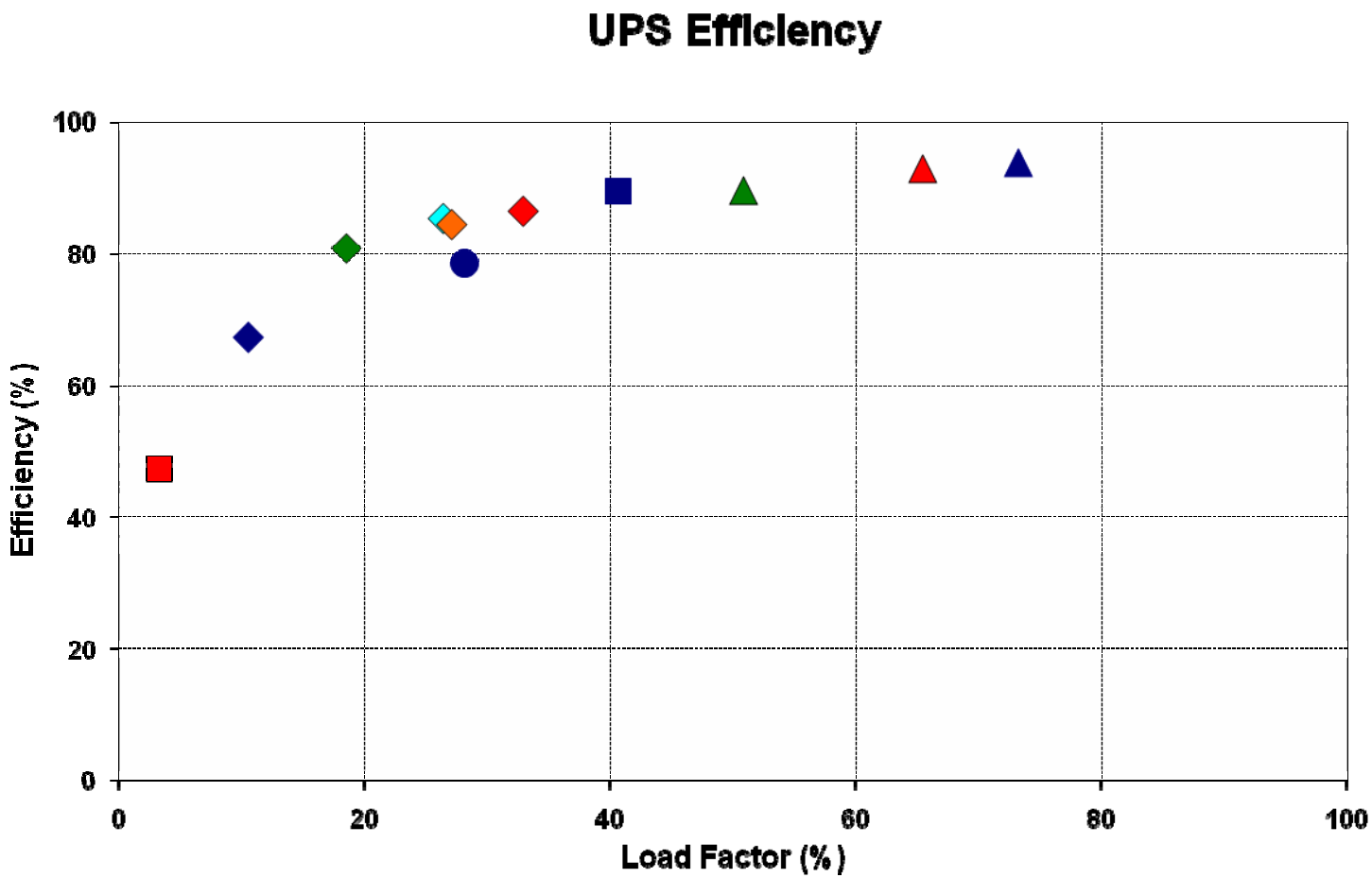
# LBNL DC Demonstration



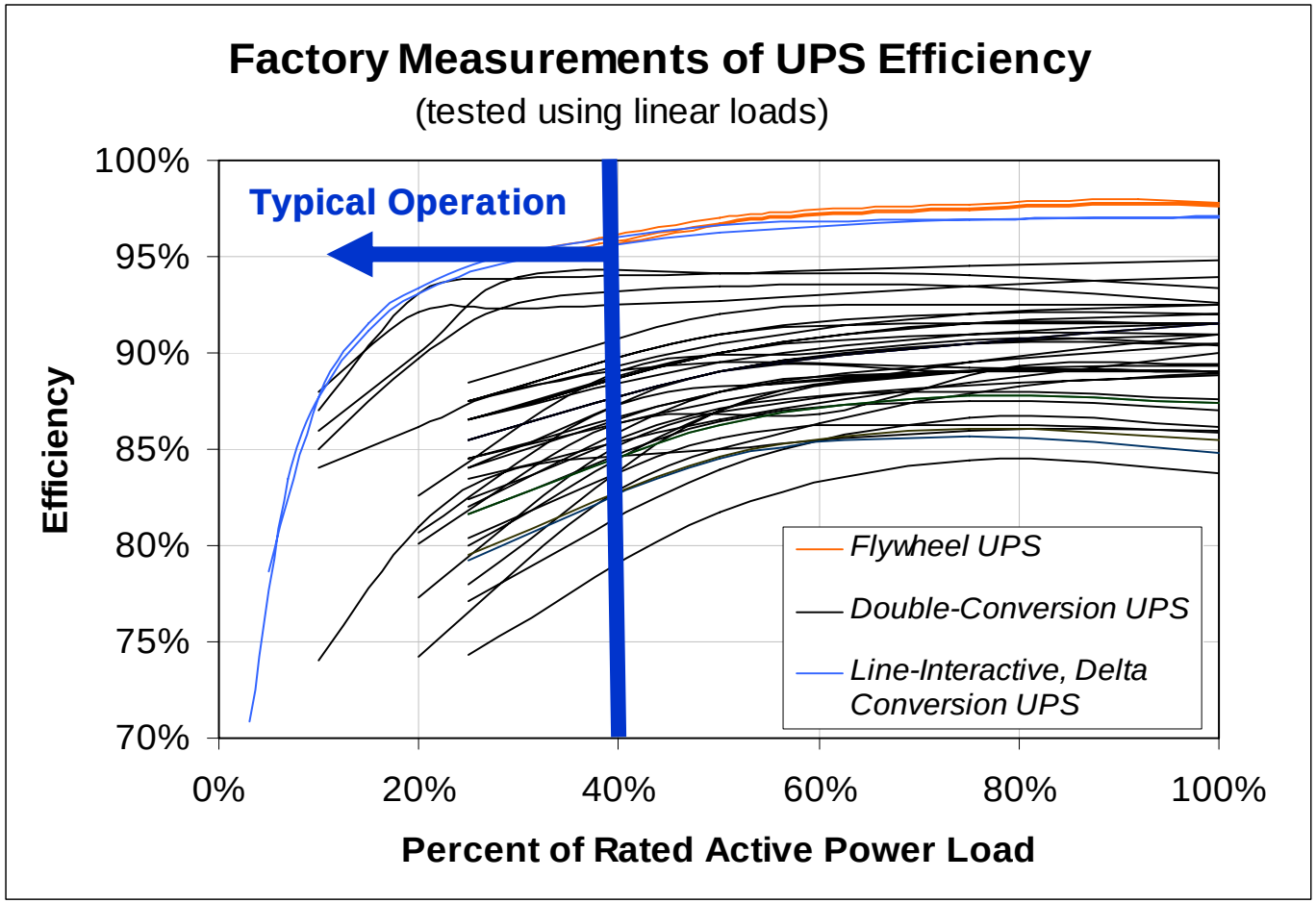
# DC Demonstration – Physical Set-up

# Video of DC demonstration

# Measured UPS performance

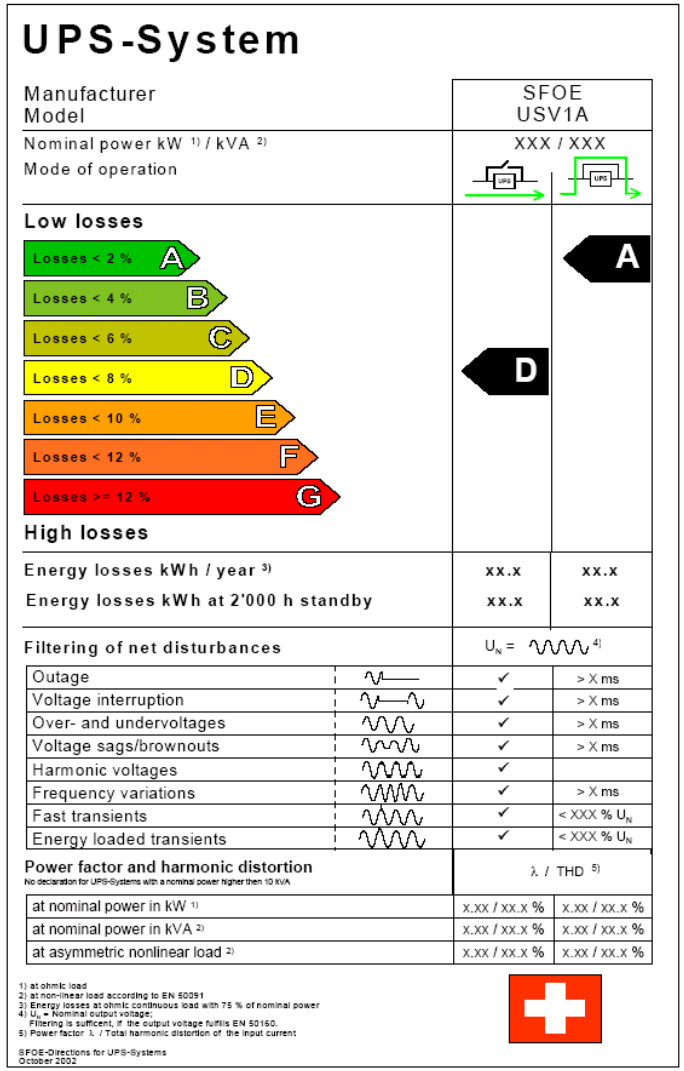


# UPS factory measurements



# UPS Draft Labeling Standard

- Based upon proposed European Standard
- Possible use in incentive programs



**UPS-System**

| Manufacturer / Model | SFOE USV1A | |
|---|---|---|
| Nominal power kW [1] / kVA [2] | XXX / XXX | |
| Mode of operation | | |
| **Low losses** | | |
| Losses < 2 % A | | A |
| Losses < 4 % B | | |
| Losses < 6 % C | | |
| Losses < 8 % D | D | |
| Losses < 10 % E | | |
| Losses < 12 % F | | |
| Losses >= 12 % G | | |
| **High losses** | | |
| Energy losses kWh / year [3] | xx.x | xx.x |
| Energy losses kWh at 2'000 h standby | xx.x | xx.x |
| **Filtering of net disturbances** | $U_N$ = [4] | |
| Outage | ✓ | > X ms |
| Voltage interruption | ✓ | > X ms |
| Over- and undervoltages | ✓ | > X ms |
| Voltage sags/brownouts | ✓ | > X ms |
| Harmonic voltages | ✓ | |
| Frequency variations | ✓ | > X ms |
| Fast transients | ✓ | < XXX % $U_N$ |
| Energy loaded transients | ✓ | < XXX % $U_N$ |
| **Power factor and harmonic distortion** (No declaration for UPS-Systems with a nominal power higher then 10 kVA) | λ / THD [5] | |
| at nominal power in kW [1] | x.xx / xx.x % | x.xx / xx.x % |
| at nominal power in kVA [2] | x.xx / xx.x % | x.xx / xx.x % |
| at asymmetric nonlinear load [2] | x.xx / xx.x % | x.xx / xx.x % |

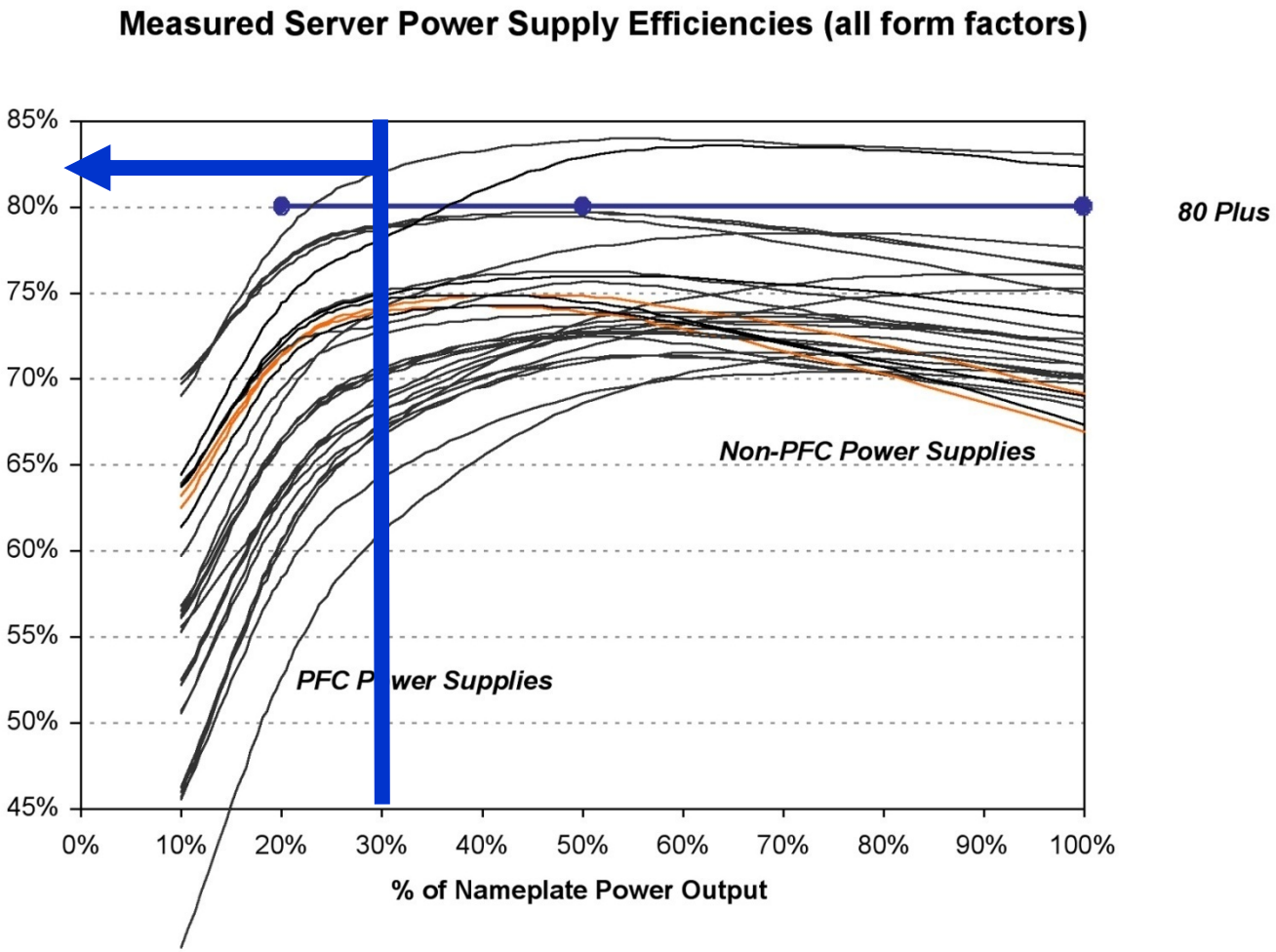
1) at ohmic load
2) at non-linear load according to EN 50091
3) Energy losses at ohmic continuous load with 75 % of nominal power
4) $U_N$ = Nominal output voltage;
Filtering is sufficent, if the output voltage fulfils EN 50160.
5) Power factor λ / Total harmonic distortion of the input current

SFOE-Directions for UPS-Systems
October 2002

# Redundancy

- Understand what redundancy costs – is it worth it?
- Different strategies have different energy penalties (e.g. 2N vs. N+1)
- Redundancy in electrical distribution always puts you down the efficiency curve

# Measured power supply efficiency



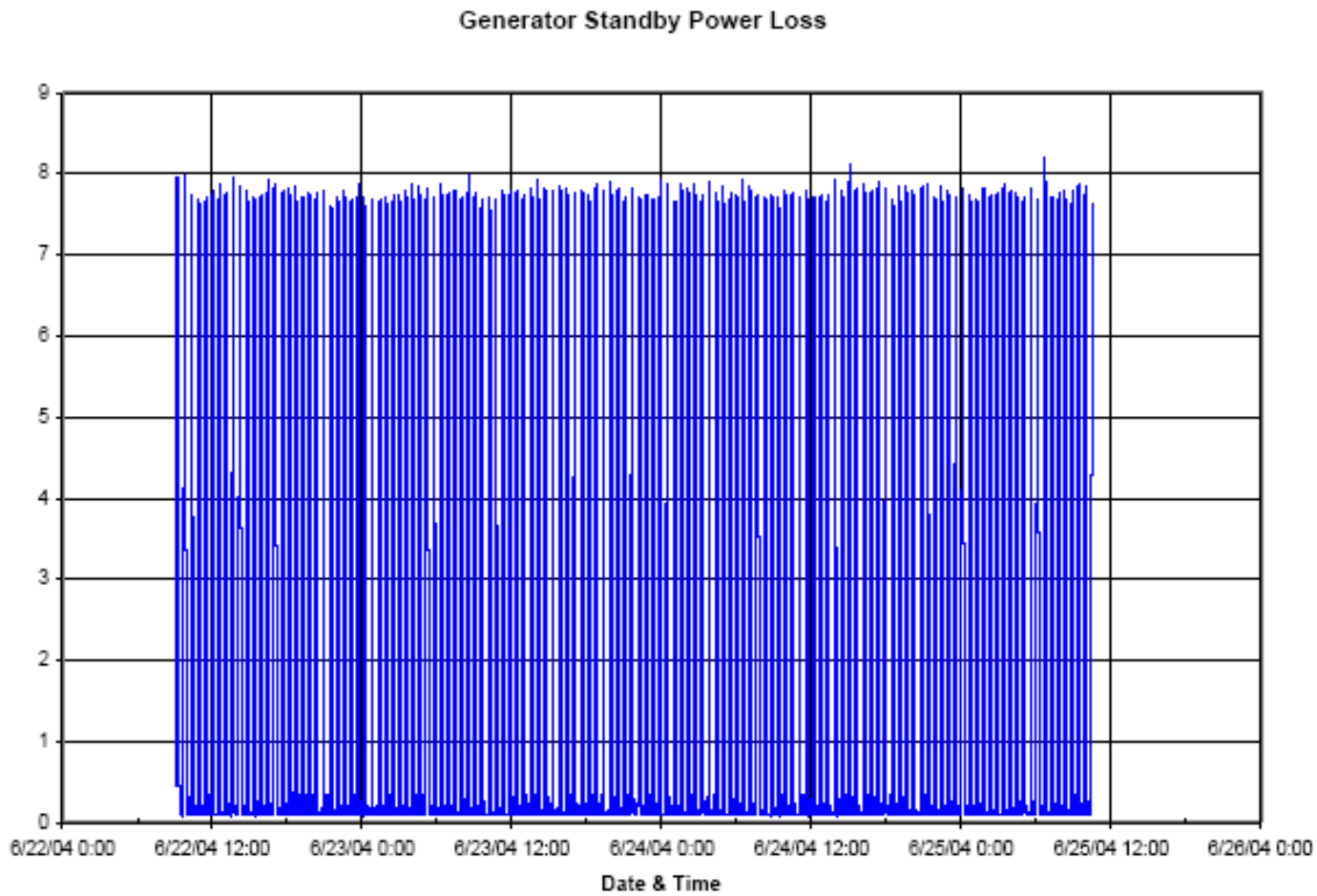
# Data center lighting

- Lights are on and nobody's home
- Lighting controls are well proven – why not use them?
- Small benefit but easy to accomplish – also saves HVAC energy
- DC lighting would compliment DC distribution

# Standby generation loss

- Several load sources
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems
- Heaters (many operating hours) use the generator will ever produce (few operating hours)
- Opportunity may be to reduce or eliminate heating, batteries, and chargers

# Standby generator heater



# On-site generation

- On-site generation with utility back-up
- Thermal host required for combined heat and power
  - Absorption or adsorption chillers
  - Other campus use
- Renewable sources (future)
  - Fuel cells
  - Solar
  - Wind

# Best Electrical Practices

- UPS systems
- Self-generation
- AC-DC distribution
- Standby generation

# Electrical take aways

- Distributing higher voltage (AC or DC) is more efficient
- Electrical power conversions are inefficient
- Highly efficient UPS's should be specified
- Highly efficient IT equipment power supplies should be specified
- Lighting is a small but low hanging opportunity
- Standby generation losses can be minimized
- On-site generation can improve reliability and efficiency